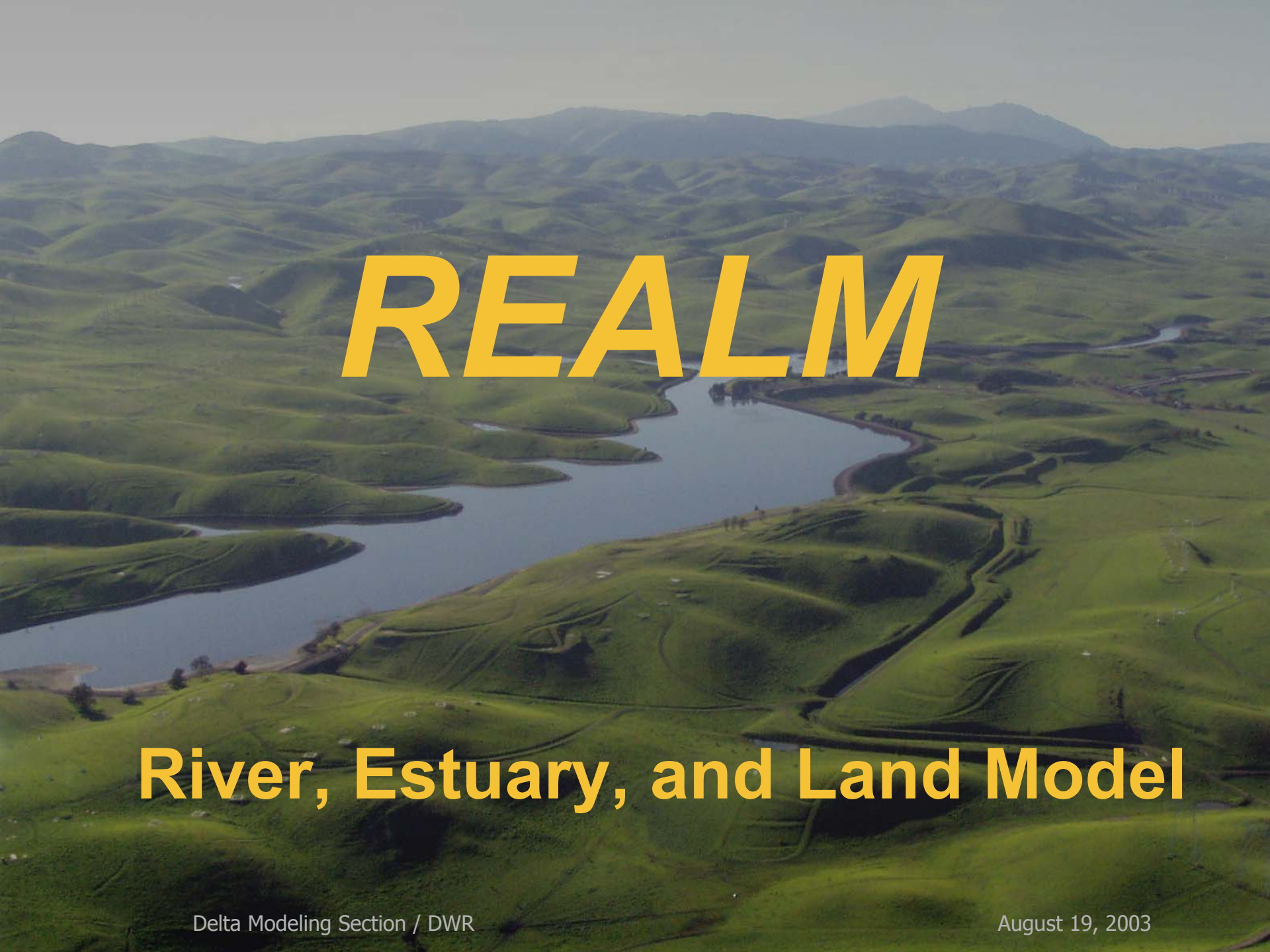


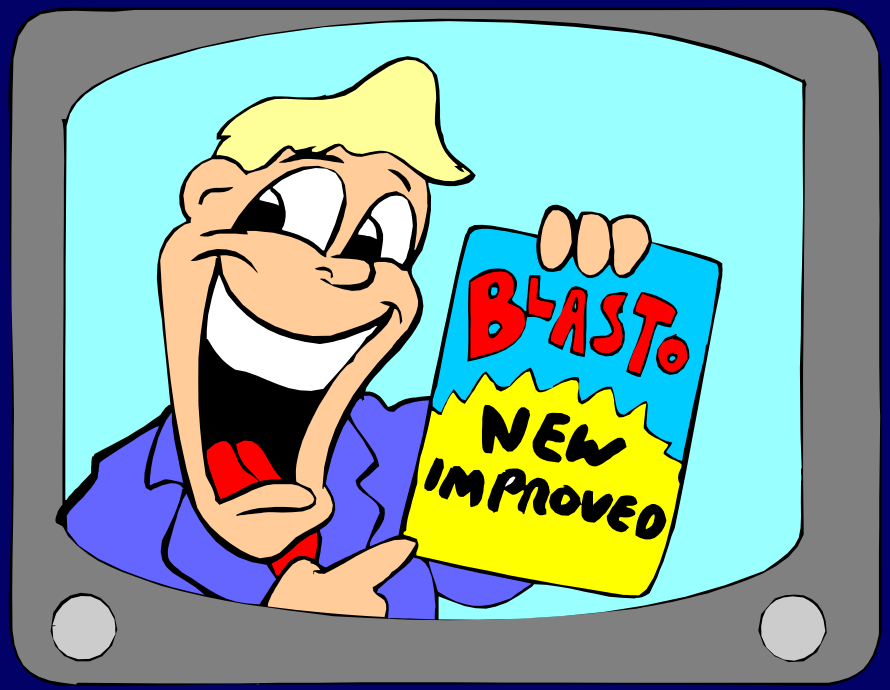
REALM

River, Estuary, and Land Model

Delta Modeling Section / DWR

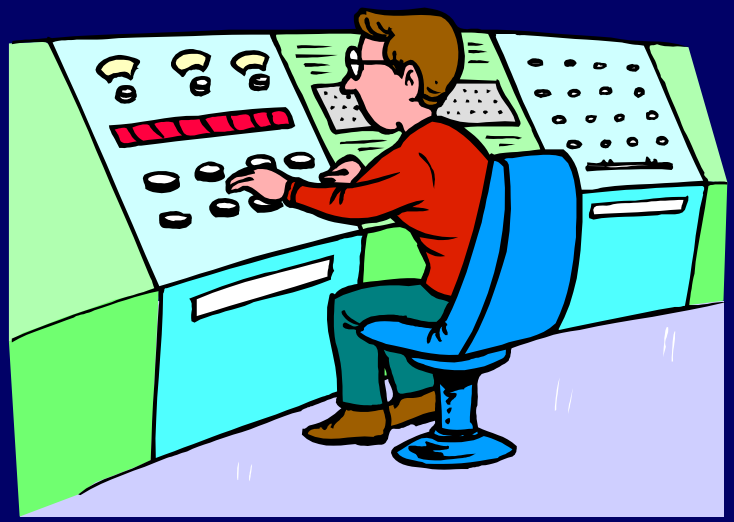
August 19, 2003

Why a New Model?



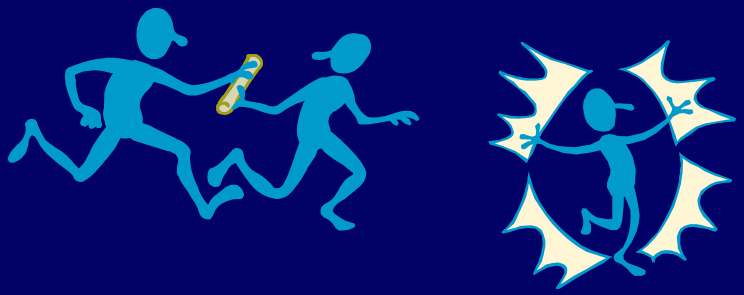
Need:

- To move beyond one-run simulations of existing and planned scenarios
- To examine range of engineered control of Delta



Need:

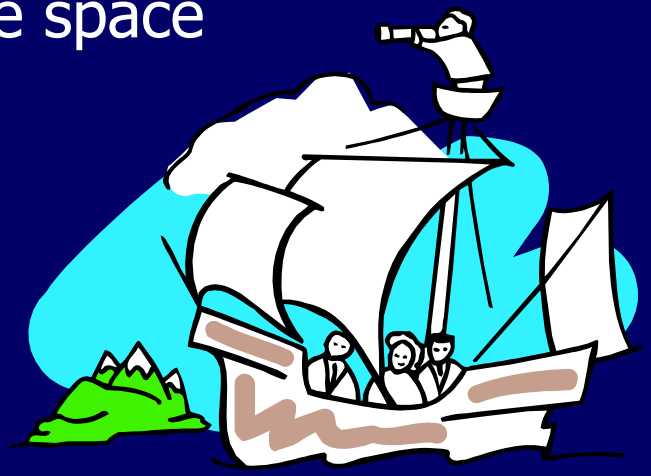
To easily adapt between large-scale and fine-detail features



Breakthrough in computing speed and accuracy for complex problems

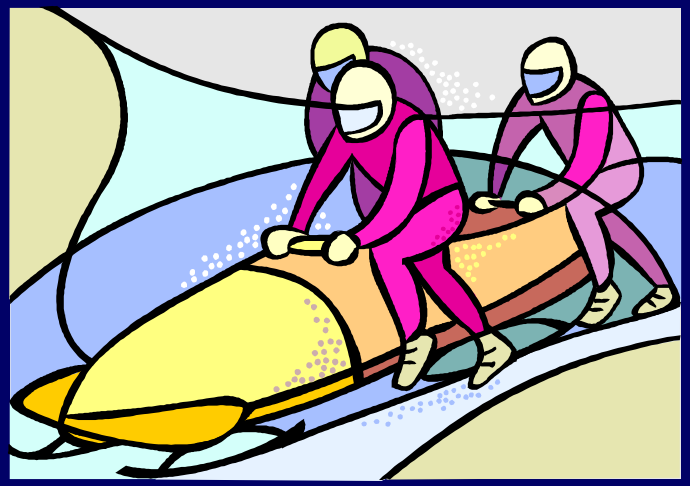
Current Situation

- Models best for simulation of a single alternative
- Exploration of alternative space difficult



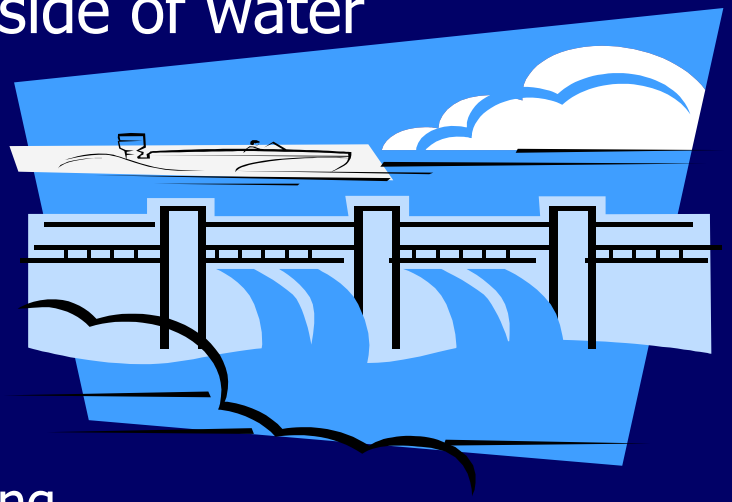
Current Situation

- Little or no use of speed enhancements:
  - Parallel processing
  - Adaptive mesh refinement



Current Situation

- Little use of techniques outside of water resources:
  - CFD methods
  - GIS
  - Software/Database engineering



What's Changed?

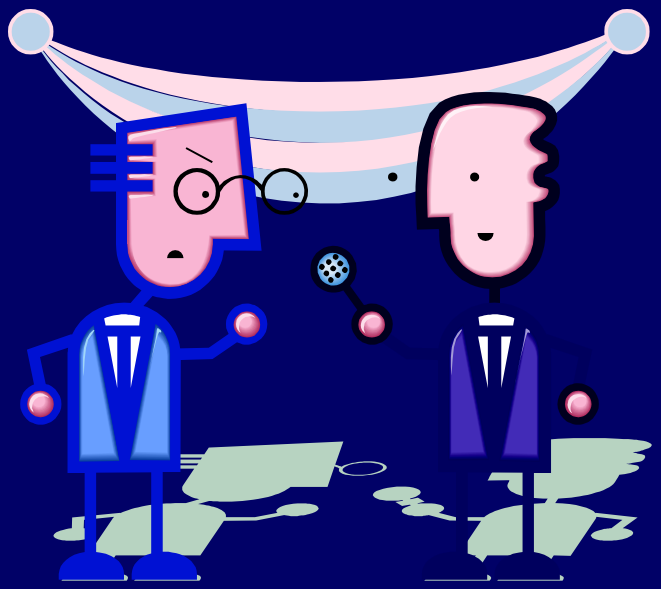
- Powerful single and parallel-computing clusters available
- Advanced computing techniques developed at LBL, National Labs, and elsewhere

What's Changed?

- Much greater quantity and quality of observed data
- Other advances in GIS, data management, and optimal control

Prologue

- Wide range of Delta workers interviewed
- Surprising interest in assistance with workers' tasks
- Strong need shown for accurate, practical models



Feature Requests

- Accurate, Delta-wide Particle Tracking
- Wetting-Drying (tidal/seasonal)
- Designed control of Delta structures (island flooding, pumping, gate operations)

What will REALM model?

- 2D hydrodynamics and water quality (eventually, mixed 2D-3D)
- Particles
- Shallow water equations with viscous momentum terms
- Irregular boundaries, wetting and drying
- Arbitrary source terms (friction, Coriolis, reaction kinetics)

Design Principles

- No Burnt Bridges
- Solicit End-User Requirements (repeatedly)
- Solicit techniques from other fields:
  - Software / Database
  - Engineering control
  - GIS
  - CFD

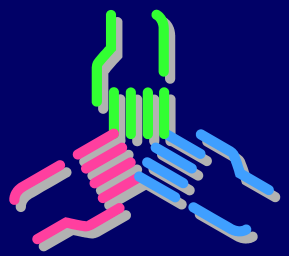
Collaboration

DWR

- Estuary physics and Chemistry
- Optimal control/Data Assimilation
- Data & Time Series Management

LBL

- High performance
- Software frameworks
- Visualization and steering
- Optimization solvers



GIS

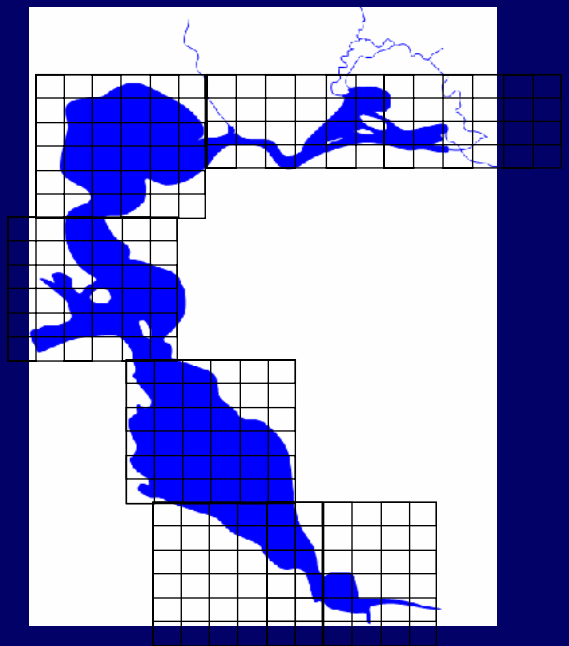
- Geographical Data
- Grid Visualization
- Run Preparation
- Output Analysis

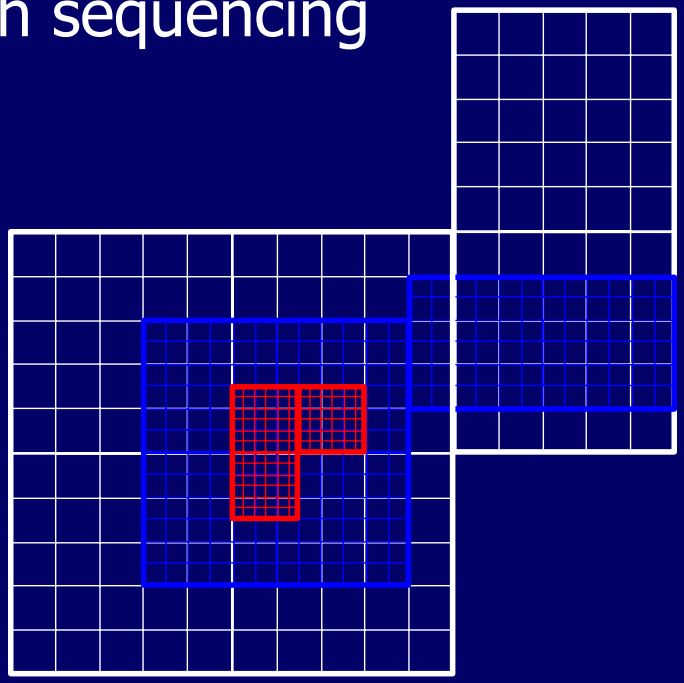
REALM Numerical Methods

- Finite volume and differences
- Cartesian grids
- Emphasize high resolution (e.g. 2nd order Godonov) methods, retrench as necessary
- Revisit conventional wisdom in light of new computing environment

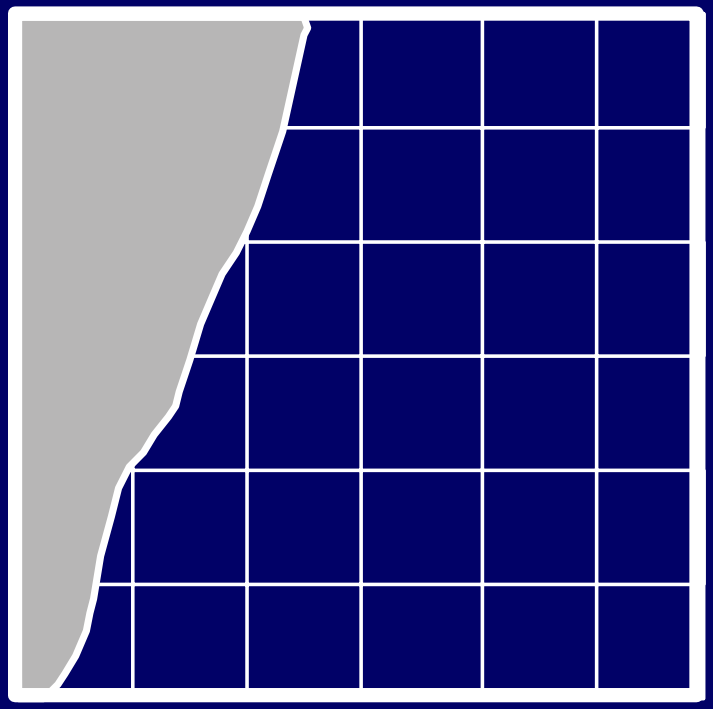
Adaptive Mesh Refinement (AMR)

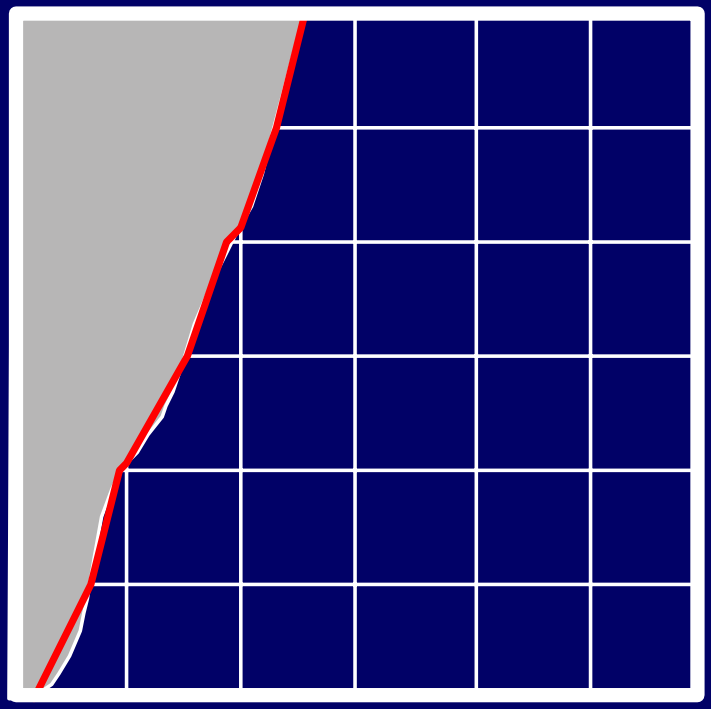
- "Minimum" effort for given accuracy
- Much easier user set-up
- (Non-adaptive) Used for "close ups"
- Optimization with mesh sequencing





Embedded Boundaries





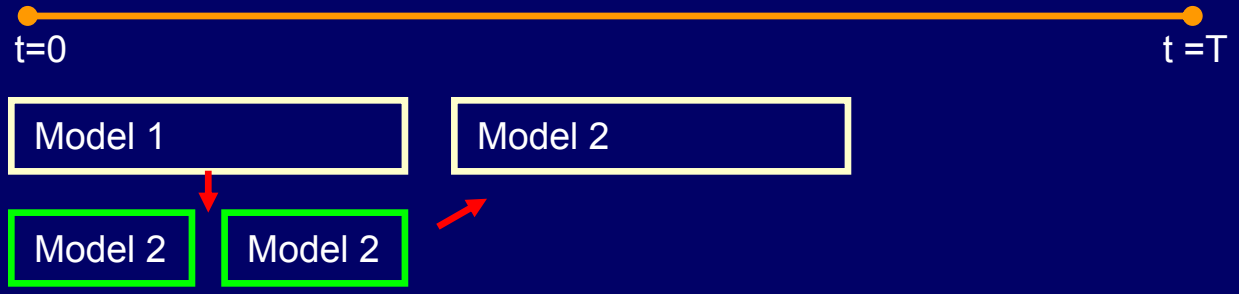
AMR + EB + Parallel = Hard

- Many small messages
- More complex data structures
- Locality and load balance trade-off is hard
- Don’t do this at home, kids!

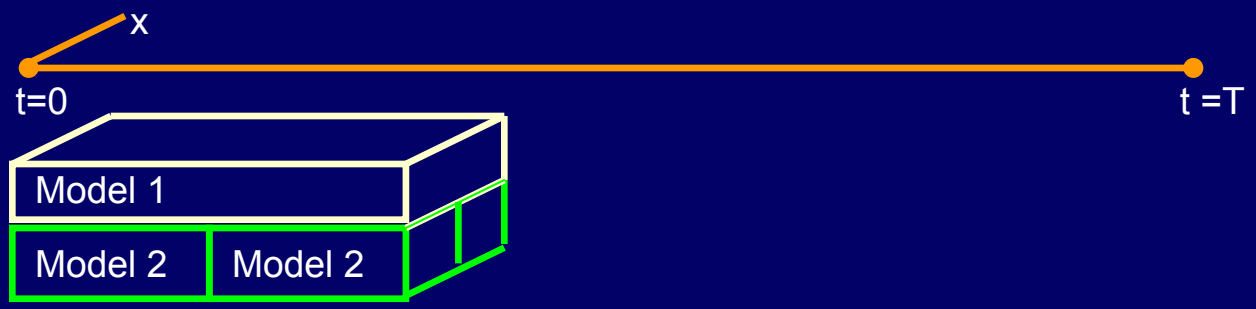
Model Coupling

Simplest

Medium



Hardest

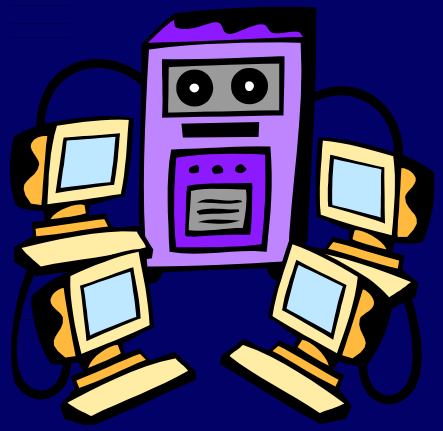


Decision-Making Support

- Model steering and interactive simulation
- Real-time data assimilation
- Adjoint-supplied gradients
  - Optimization and automatic calibration
  - Multi-objective simulation

Data Assimilation

Models With Error



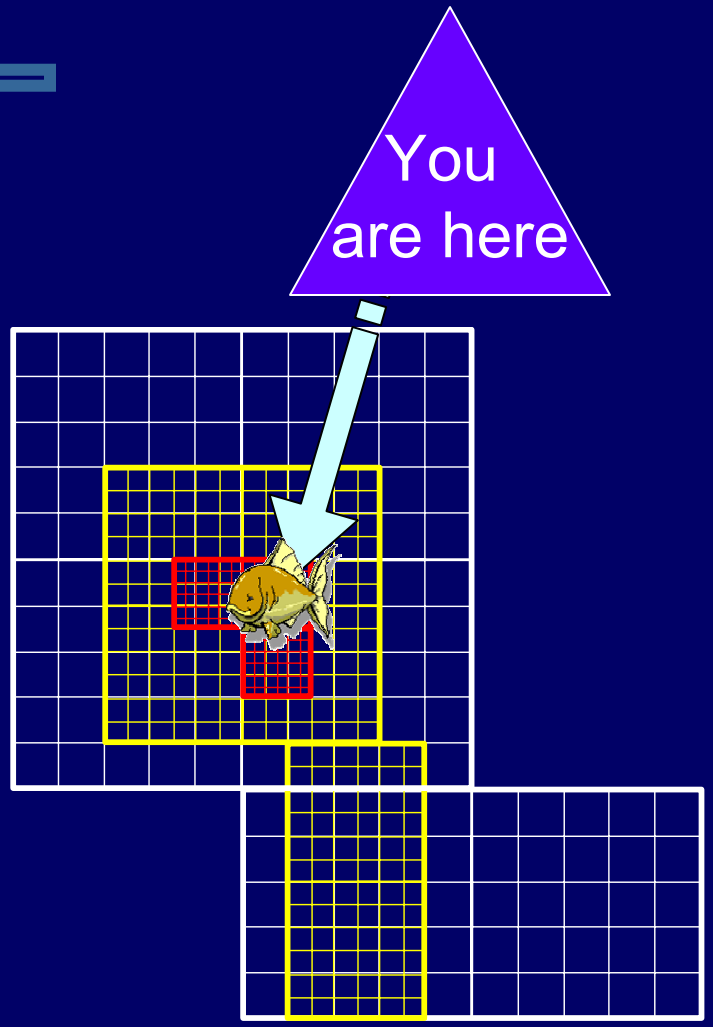
Noisy Data

Extended Kalman Filter/
Adjoint Data Assimilation

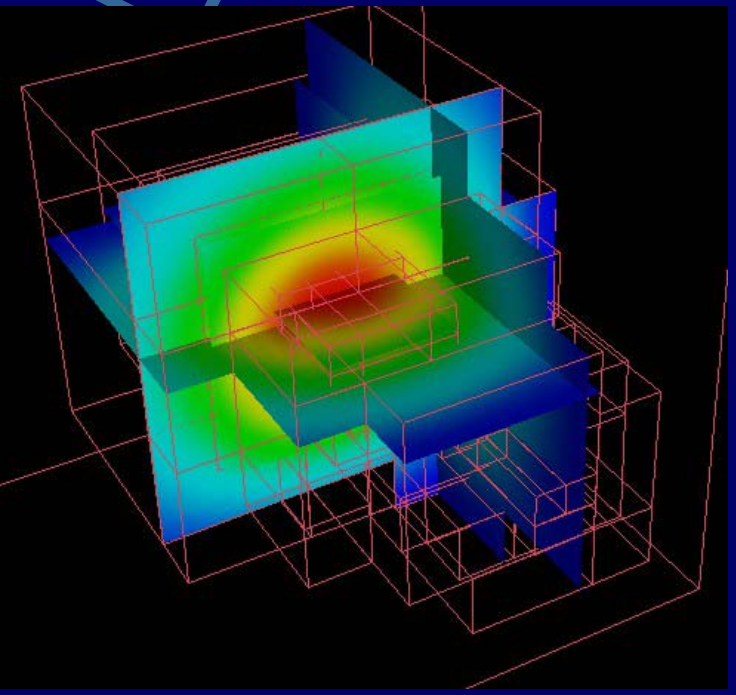
Example:

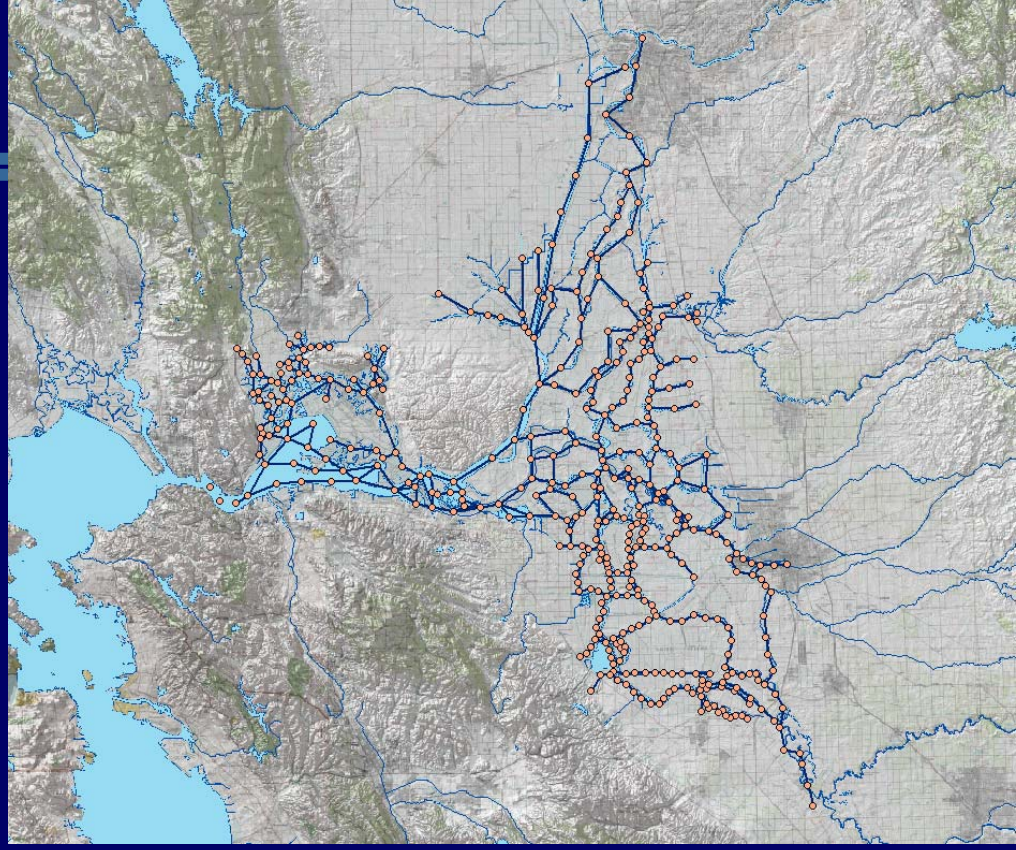
Particle Tracking

- Track particles through Delta
- Adaptive grid for high local accuracy
- Passive + Behavior
- Steering! Be the smelt



Visualization





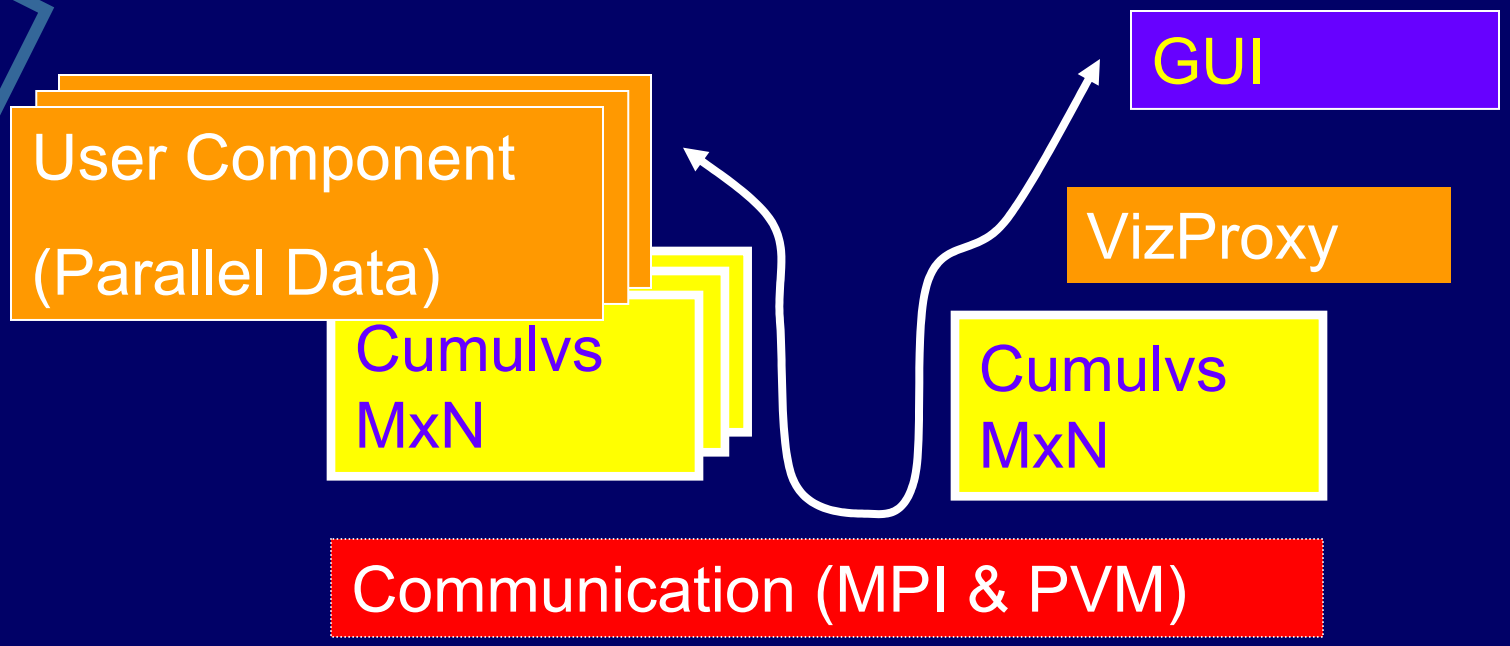
- Interactive Interface
- Production Graphics
- Spatial + Time Series
- Emphasize standards: GIS + HDF5

Steering

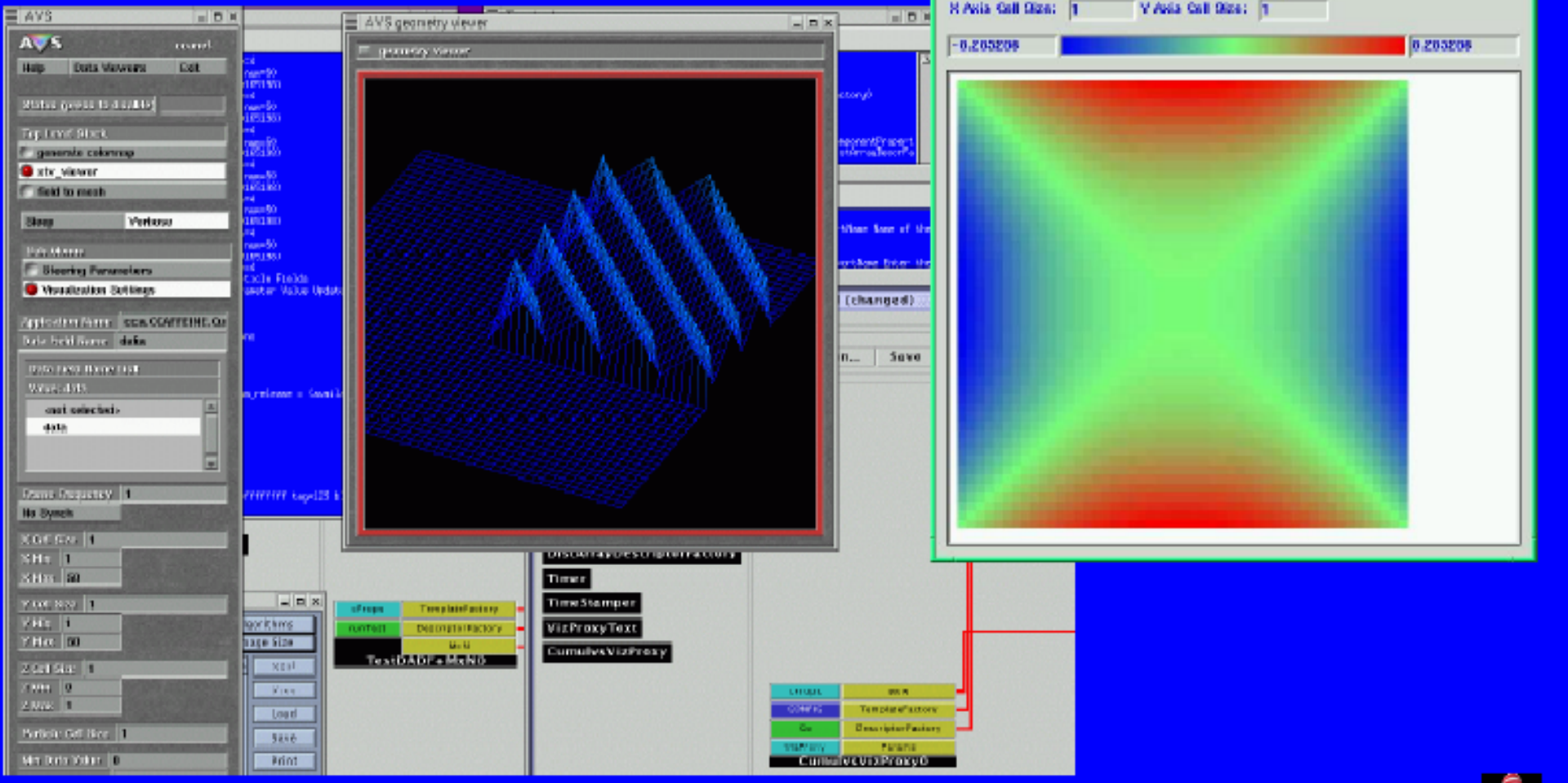
- Steering uses an interface to “compiled assets.”
  - GUI/GIS, Python, ….
- Rich command structure lets users “program” within simulation paradigm
- Exploit interactivity
- Mixed architectures OK
- The tricky thing is parallelism BUT …

Acknowledgement:: Pat Miller LLNL

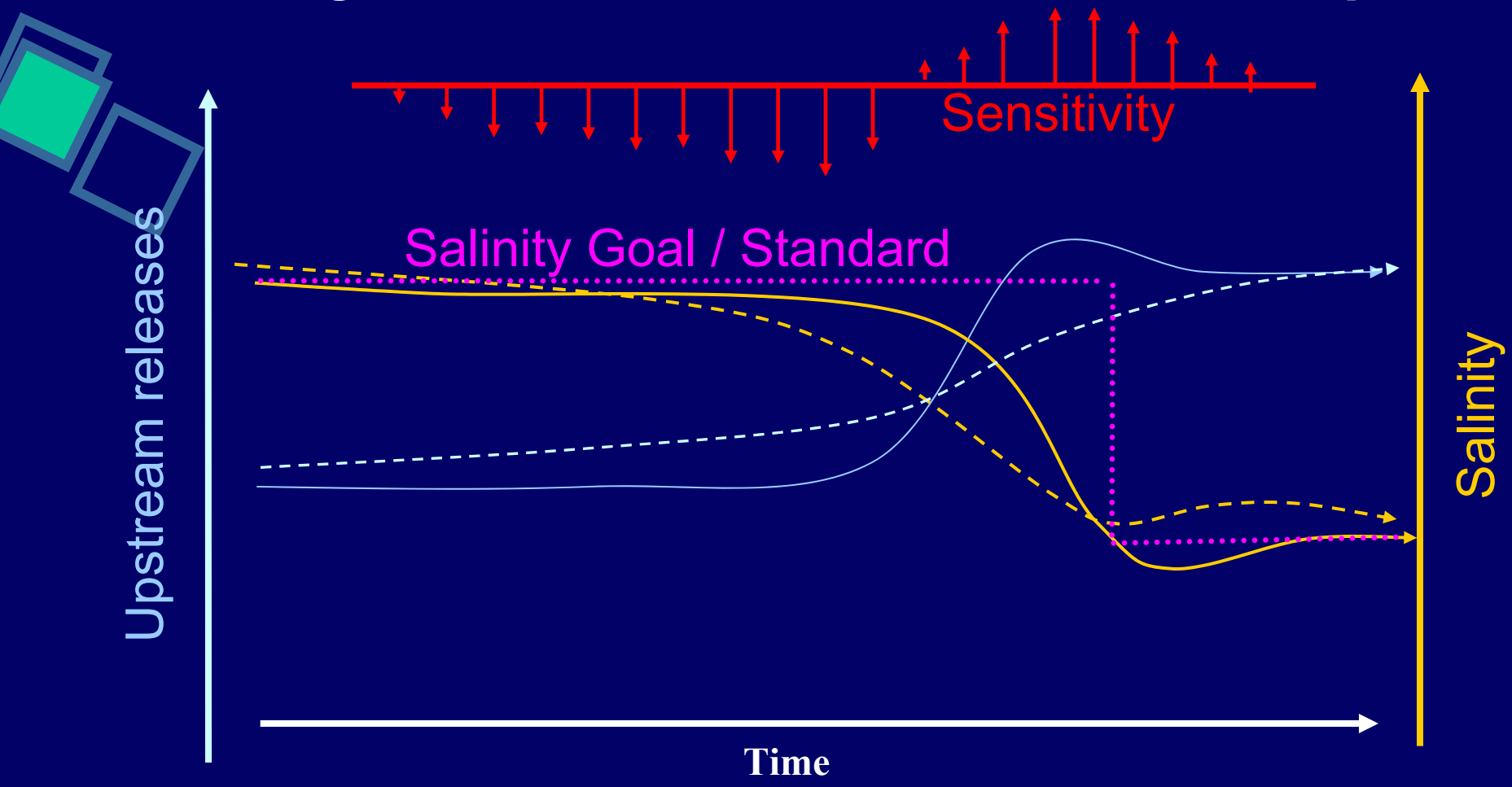
Cumulvs Framework for Model Steering/Visualization



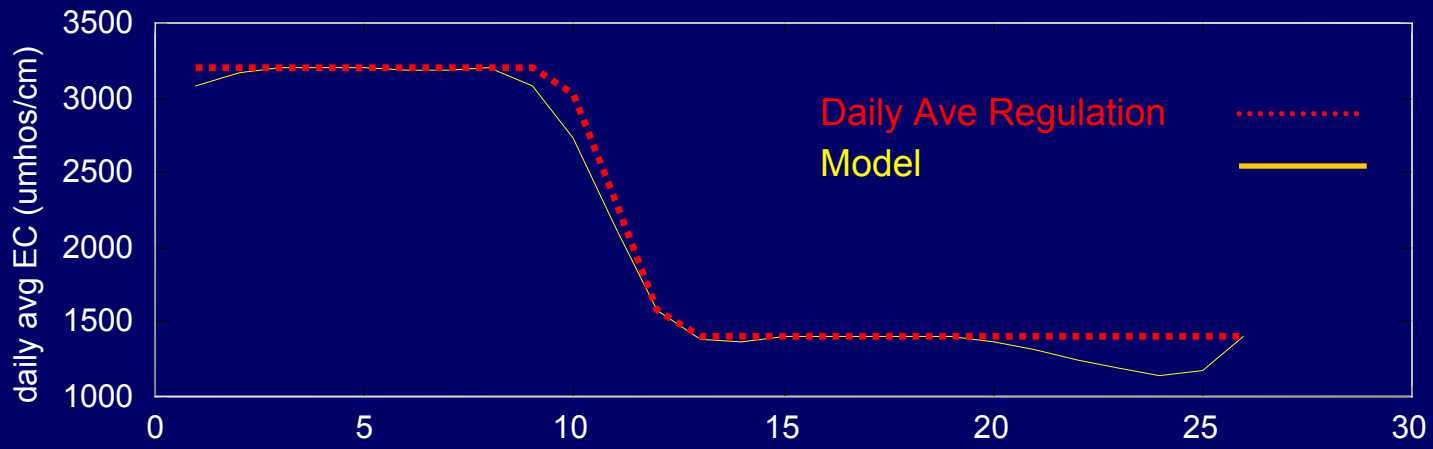
CumulvsMxN Demo Shots

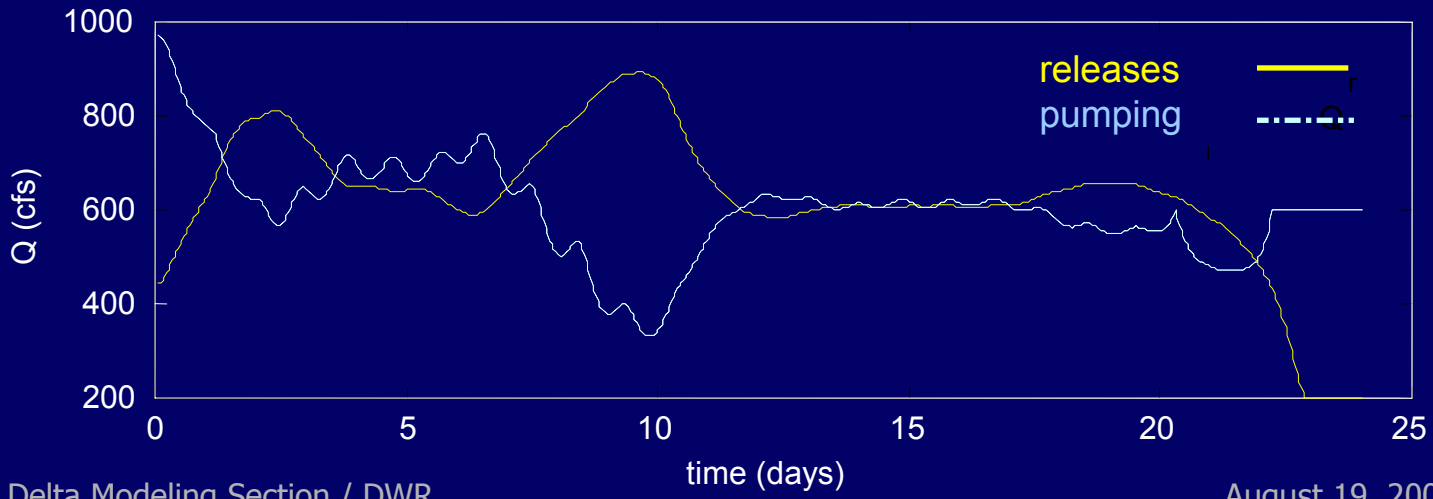


Adjoint Models and Sensitivity

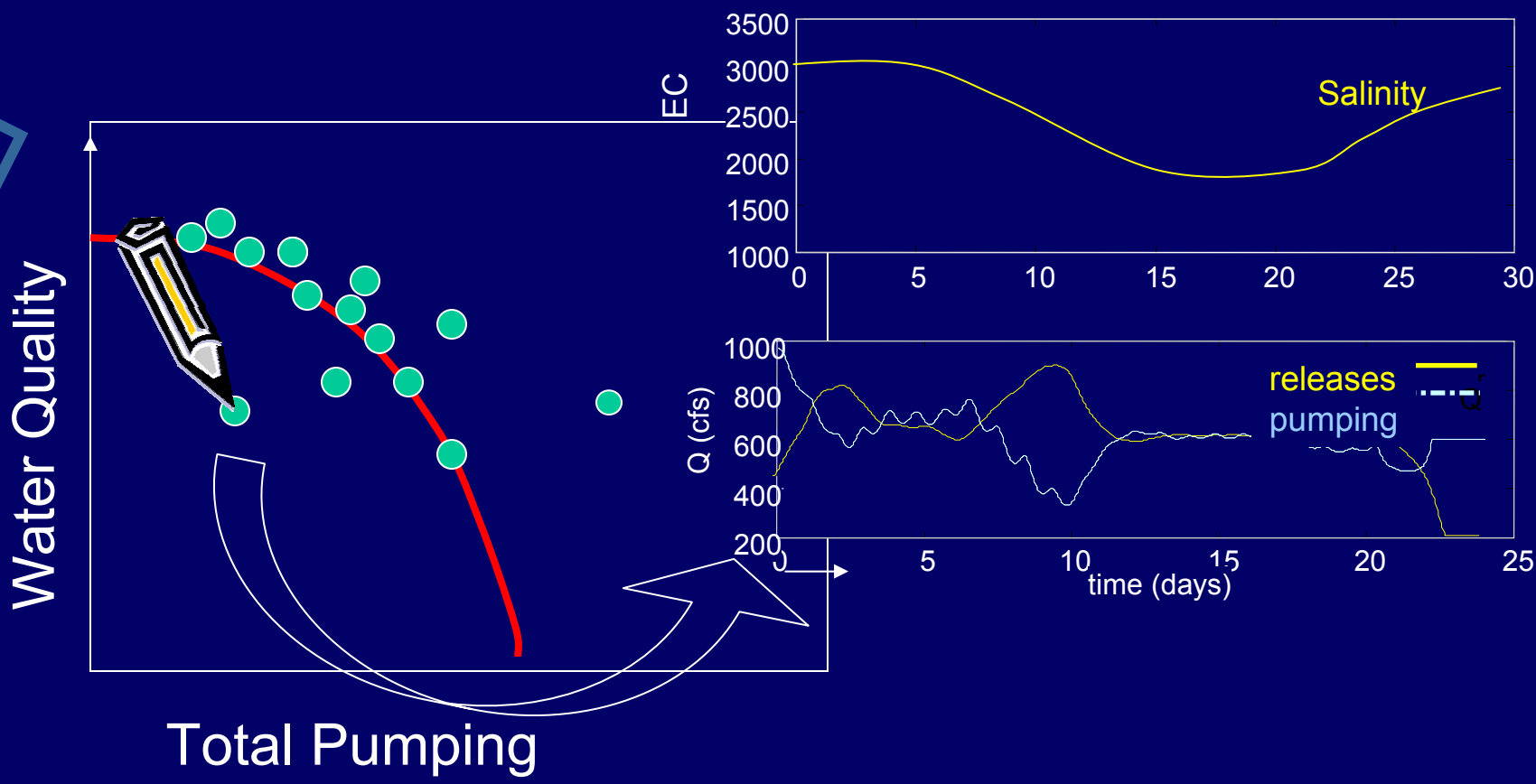


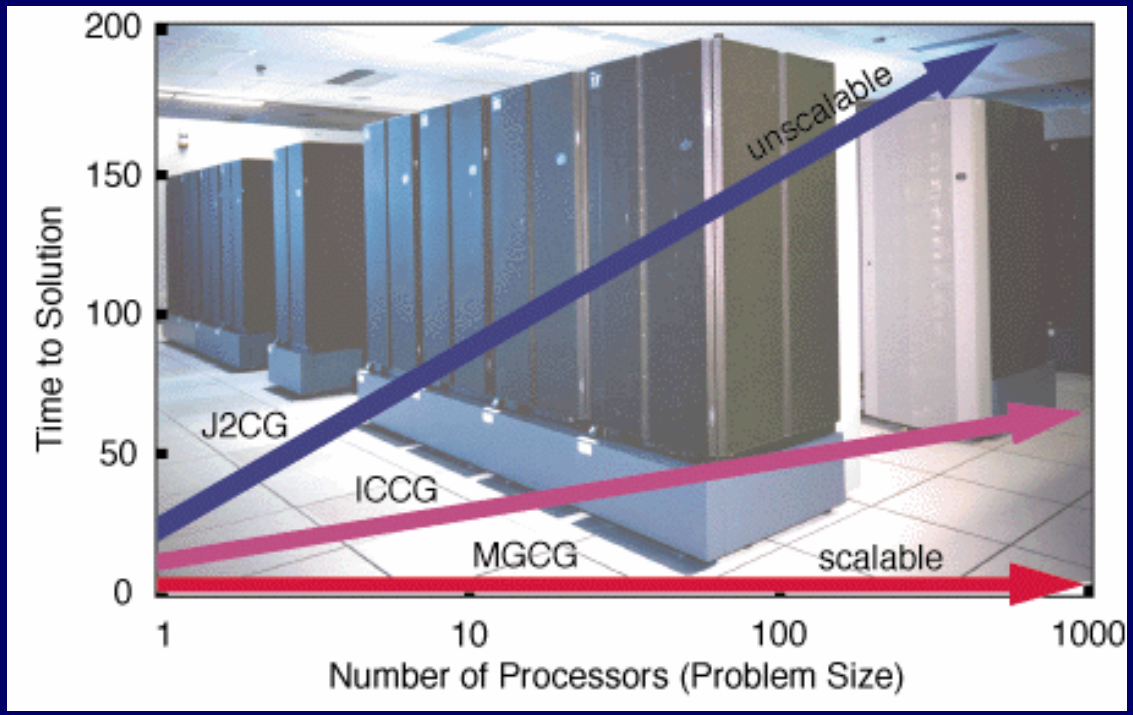
Water Cost: Single Objective





Water Cost: Exploring Tradeoffs




200
150
100
50
0
Time to Solution
unscalable
J2CG
ICCG
MGCG
scalable
1
10
100
1000
Number of Processors (Problem Size)

REALM Phase I (12-18 months)

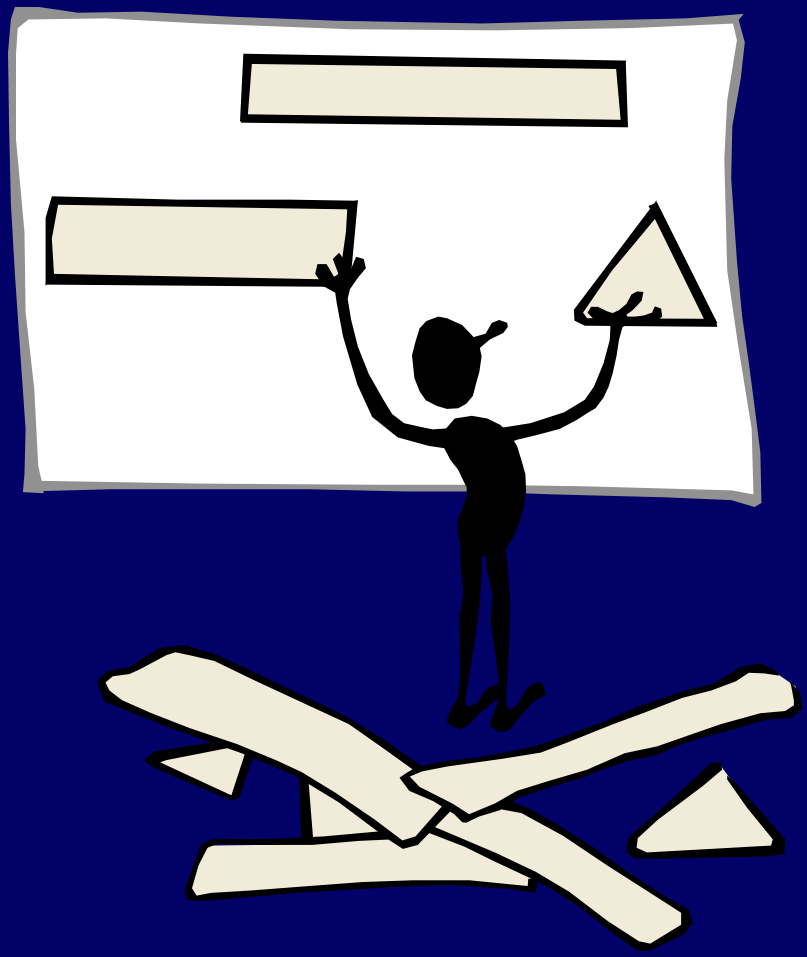
- 2D model estuary hydrodynamic and water quality model
- GIS front end for input and mesh development
- Visualization hookup to output storage format (HDF5)
- Mathematical hooks for optimization and data assimilation

REALM Phase II (12-18 months)

- Adaptive 3D calculation of stratified flow and special study areas
- Adaptive particle modeling
- Prototype data assimilation
- Performance and usability enhancements
- Emphasize design cycle based on users

Where Are We?

- Conceptual design finished
- Major tasks and leadpersons identified



Where Are We?

- Contracts being developed:
  - LBL work
  - GIS work
  - Contract programmer

REALM

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Ralph Finch rfinch@water.ca.gov